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【수신처】 특허청장

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【명칭의 영문표기】 OPTOMECHA CO., LTD. et al

【주소의 영문표기】 #102, Daerung Technotown 5th, 493, Gasan-dong, Geumchun-gu, Seoul 153-803 Republic of Korea

【국적】 KR

【대리인】

【성명의 영문표기】 KIM, Seon-Min

【주소의 영문표기】 LEE & KIM, 5th Floor, New-Seoul Bldg. 828-8, Yoksam 1-Dong, Kangnam-Ku, Seoul 135-935 Republic of Korea

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【첨부서류】 1.보정내용 및 이유를 기재한 설명서_1통

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3.위임장_1통

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filter layer of a substrate and is sensed by the photoelectric elements.

The present invention takes notice of radical reasons of problems of the conventional image sensor, and solves the problems to raise efficiency of the image sensor. The conventional methods stick to resultant phenomena rather than radical countermeasures, and thus rarely improve efficiency of the image sensor. However, the present invention can considerably improve efficiency of the image sensor.

For this, the present invention is based on two very simple principles.

The first principle can be obtained from consideration of problems of the conventional image sensor that efficiency is bad. The optical efficiency of the conventional image sensor is reduced because light is slantingly incident on micro lenses.

Accordingly, the present invention makes light incident on the micro lenses at a right angle, or makes the micro lenses themselves perform this function (aspheric micro lenses). It is very meaningful that light is incident at a right angle. It implies that light is incident at a right angle on the micro lenses of peripheral pixels of the image sensor as well as the micro lenses of central pixels.

The second principle relates to a way of embodying the first principle, namely a way for making light incident on the surface of the image sensor at a right angle. Here, the present invention uses the Snell's law, a refraction law for controlling refractions when light passes through the interface between different media, and also uses the reflection law.

An optical path of light is changed due to refraction or reflection. Here, let's presume that the optical path of light slantingly incident on the peripheral pixels of the image sensor is changed by a refraction or reflection element and then light is incident on the micro lenses at a right angle.

Because light is incident on the micro lenses at a right angle, an angle of light refracted or reflected by the refraction or reflection element can be regarded as a fixed value. Therefore, we can consider that an inclination angle of light incident on the refraction or reflection element and a gradient value of an incident surface of the refraction

or reflection element are mutually dependent variables.

That is, when the inclination angle of light is changed, the gradient value of the incident surface has to be changed, to keep refracted or reflected light parallel to an optical axis. It implies that the present invention can make refracted or reflected light parallel to the optical axis by using optical path conversion elements which have different tangent line gradients on the corresponding parts of the incident surfaces according to distances between the corresponding parts and the center of the image sensor.

The present invention originates from these very simple but important radical principles, which will later be explained in more detail with reference to Figs. 8 to 10 and Figs. 14 to 16.

In order to achieve the above-described object of the invention, there is provided an image sensor comprising: a substrate in which an array of photoelectric elements is formed; and an array of optical path conversion elements for converting optical paths of incident light formed at a light incident side of the substrate so that the optical path converted light may be incident on the substrate, each optical path conversion element being formed to match with each photoelectric element, wherein an incident surface of each optical path conversion element has a tangent line gradient value to convert the optical path of light incident slantingly on a peripheral area of the image sensor at a larger inclination angle as the peripheral area is away from the center of the image sensor to be identical with the optical path of light incident vertically on a central area of the image sensor to counterbalance the inclination angle of light incident on the peripheral area of the image sensor, the tangent line gradient values of corresponding parts of the incident surfaces of the optical path conversion elements at an identical distance from the respective matching photoelectric elements being different from one another according to distances between the corresponding parts and the center of the image sensor.

Preferably, the optical path conversion elements are micro prisms or micro reflecting mirrors having different incident surface gradient values according to the distances from the center of the image sensor.

Here, the single image sensor can include both the micro prism type optical path conversion elements and the micro reflecting mirror type optical path conversion elements.

In addition, the single optical path conversion element can include combinations of a plurality of micro prisms.

The micro prism type optical path conversion elements and the flat surface micro reflecting mirror type optical path conversion elements convert the optical path of light to be parallel to the optical axis.

Preferably, the image sensor includes micro lenses, and the micro lenses are positioned in the optical path of light converted by the optical path conversion elements, for condensing light to the photoelectric elements.

Preferable, the optical path conversion elements are aspheric micro lenses or aspheric micro reflecting mirrors.

The single image sensor can include both the aspheric micro lens type optical path conversion elements and the aspheric micro reflecting mirror type optical path conversion elements.

Preferably, the optical path conversion elements are so positioned that the centers of the optical path conversion elements are offset from the centers of the photoelectric elements according to the distances from the center of the image sensor.

Preferably, when the single image sensor is divided into a plurality of regions according to the distances from its center, the optical path conversion elements in the same region have the identical tangent line gradient value on the corresponding parts of the incident surfaces, but the optical path conversion elements in the different regions have different tangent line gradient values on the corresponding parts of the incident surfaces according to the distances between the corresponding parts and the center of the image sensor.

According to another aspect of the invention, there is provided a method for fabricating an image sensor in which optical path conversion elements are formed according to a photolithography process using a gray scale mask, combinations of the photolithography process and a reactive ion etching process, or combinations of the photolithography process, the reactive ion etching process, and an UV-molding process.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates a basic structure of a conventional image sensor which does not have an array of micro lenses;

Fig. 2 illustrates a basic structure of a conventional image sensor including

an array of micro lenses;

Fig. 3 illustrates one example of a system using an image sensor;

Fig. 4 illustrates low optical efficiency of peripheral pixels of the image sensor of Fig. 2;

Fig. 5 illustrates another example of a conventional image sensor wherein micro lenses are arranged on different planes according to distances from the center of the image sensor;

Fig. 6 illustrates yet another example of a conventional image sensor wherein micro lenses of different sizes are arranged according to distances from the center of the image sensor;

Fig. 7 illustrates yet another example of a conventional image sensor wherein micro lenses are arranged in deviated positions from photoelectric elements according to distances from the center of the image sensor;

Fig. 8 is a concept view showing that a prism can vary an optical path of light;

Fig. 9 illustrates the refraction law of light, especially light passing through the prism of Fig. 8;

Fig. 10 illustrates relations between an inclination angle and a gradient value of an incident surface for making light refracted by the prism parallel to an optical axis;

Figs. 11a and 11b illustrate image sensors including an array of micro prisms as optical path conversion elements in accordance with one embodiment of the present invention, wherein Fig. 11a shows the image sensor including a single array of micro prisms, and Fig. 11b shows the image sensor including a double array of micro prisms;

Fig. 12 illustrates an image sensor including an array of micro prisms and an array of micro lenses as optical path conversion elements in accordance with another embodiment of the present invention;

Fig. 13 illustrates an image sensor including an array of aspheric micro lenses in accordance with yet another embodiment of the present invention;

Fig. 14 is a concept view showing that a reflecting mirror can vary an optical

path of light;

Fig. 15 illustrates the reflection law of light, especially light reflected by the reflecting mirror of Fig. 14;

Fig. 16 illustrates relations between an inclination angle and a gradient value of an incident surface for making light reflected by the reflecting mirror parallel to an optical axis;

Fig. 17 illustrates an image sensor including an array of micro reflecting mirrors as optical path conversion elements in accordance with yet another embodiment of the present invention;

Fig. 18 illustrates an image sensor including an array of micro reflecting mirrors and an array of micro lenses as optical path conversion elements in accordance with yet another embodiment of the present invention;

Fig. 19 illustrates an image sensor including an array of aspheric micro reflecting mirrors in accordance with yet another embodiment of the present invention;

Figs. 20a to 20c respectively illustrate processes for fabricating an image sensor in accordance with various embodiments of the present invention;

Figs. 21a and 21b illustrate simulation results for the image sensor including the array of micro lenses in Fig. 2, wherein Fig. 21a shows an optical path of light, and Fig. 21b shows distribution of light intensity in photoelectric element; and

Figs. 22a and 22b illustrate simulation results for the image sensor including the array of micro prisms and the array of micro lenses in Fig. 12, wherein Fig. 22a shows an optical path of light, and Fig. 22b shows distribution of light intensity in photoelectric element.

BEST MODE FOR CARRYING OUT THE INVENTION

An image sensor and a method for fabricating the same in accordance with preferred embodiments of the present invention will now be described in detail with reference to the accompanying drawings.

Fig. 8 is a concept view showing that a prism 10 can vary an optical path of light.

As illustrated in Fig. 8, the micro prism 10 converts the optical path of light to be parallel to an optical axis in order to prevent reduction of optical efficiency due to light slantingly incident on peripheral pixels of an image sensor.

The relations between an inclination angle of light incident on the surface of the prism 10, an angle of refracted light and a gradient value of an incident surface of the prism 10 will now be explained with reference to Fig. 9.

Fig. 9 illustrates the refraction law of light, especially light passing through the prism 8 of Fig. 8.

Fig. 9 shows a refraction path of light when light is incident on an interface between different media having a gradient of 'α'. When it is presumed that an angle of incident light to a normal line of the interface is 'θ_1', an angle of refracted light to the normal line of the interface is 'θ_2', a refraction index of the medium in the incident side is 'n_1' and a refraction index of the medium in the refraction side is 'n_2', the Snell's law is represented by following formula (1):

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \quad \cdots\cdots\cdots\cdots\cdots (1)$$

Here, when it is presumed that the gradient of the interface is 'α', an inclination angle of incident light to the optical axis is 'ϕ_1' and an angle of refracted light to the optical axis is 'ϕ_2', and they are introduced to formula (1), we can obtain following formula (2):

$$\tan\alpha = \frac{n_1 \sin\phi_1 - n_2 \sin\phi_2}{n_1 \cos\phi_1 - n_2 \cos\phi_2} \quad \cdots\cdots\cdots\cdots\cdots (2)$$

In case that light is vertically refracted (ϕ_2=0) through the surface of the prism 10, the gradient α of the incident surface of the prism 10 is represented by following formula (3) with regard to the inclination angle ϕ_1 of incident light and the refraction

indexes n_1 and n_2 of the media:

$$\alpha = \tan^{-1}\left(\frac{n_1 \sin\phi_1}{n_1 \cos\phi_1 - n_2}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Fig. 10 illustrates relations between the inclination angle and the gradient value of the incident surface for making light refracted by the prism 8 parallel to the optical axis.

Fig. 10 shows the gradient α of the incident surface of the prism 10 according to the inclination angle ϕ_1 of light incident on the incident surface of the prism 10 for making refracted light parallel to the optical axis, when the refraction index of the medium in the incident side is '1' and the refraction index of the medium in the refraction side is '1.5'.

Here, two points must be noted.

First, as the inclination angle ϕ_1 increases, that is, in the peripheral pixels of the image sensor, the gradient of the incident surface of the prism 10 increases in the negative direction, which will later be explained with reference to Fig. 11a.

Second, when the refraction index of the prism 10 is larger than that of the medium in the incident side, the gradient of the incident surface of the prism 10 has a negative value, and reversely, when the refraction index of the prism 10 is smaller than that of the medium in the incident side, the gradient of the incident surface of the prism 10 has a positive value, which will later be explained with reference to Fig. 11b.

Figs. 11a and 11b illustrate image sensors including an array of micro prisms 10 as optical path conversion elements in accordance with one embodiment of the present invention. Here, Fig. 11a shows the image sensor including a single array of micro prisms 10, and Fig. 11b shows the image sensor including a double array of micro prisms 10a and 10b.

Figs. 11a and 11b show that the array of micro prisms 10 having different incident surface gradients can make light incident at different angles on each pixel refracted parallel to an optical axis.

lenses.

Fig. 13 illustrates the image sensor including the array of aspheric micro lenses 11 in accordance with yet another embodiment of the present invention.

As illustrated in Fig. 13, tangent lines to the corresponding parts of the incident surfaces have different gradients according to distances between the corresponding parts and the center of the image sensor, and thus aspheric micro lenses 11 in different shapes are arranged to convert optical paths of slantingly incident light and condense light to photoelectric elements 1. That is, the aspheric micro lens and aspheric micro reflecting mirror have different tangent line gradient values on individual parts of the incident surface of the same optical path conversion element to condense incident light to the photoelectric element. Therefore, the aspheric micro lenses 11 perform functions of micro prisms 10 as optical path conversion elements as well as functions of micro lenses 5 as condensers.

Differently from the micro prisms 10, tangent line gradients are different at each point on the incident surface of one aspheric micro lens 11. The tangent line gradients at each point can be calculated by formula (2).

Figs. 8 to 13 show that we can improve optical efficiency of the image sensor by using the refraction law. The reflection law has the same effects as discussed later.

Fig. 14 is a concept view showing that a reflecting mirror 12 can vary an optical path of light.

Relations between an inclination angle of light incident on the surface of the reflecting mirror 12, an angle of reflected light and a gradient value of an incident surface of the reflecting mirror 12 will now be described with reference to Fig. 15.

Fig. 15 illustrates the reflection law of light, especially light incident on the reflecting mirror 12 of Fig. 14.

Fig. 15 shows an angle of reflected light when light is incident on the incident surface having a gradient of β. When it is presumed that an angle of incident light to a normal line of the incident surface is 'θ_3' and an angle of reflected light to a normal line of the incident surface is 'θ_4', the reflection law is represented by formula (4):

$$\theta_3 = \theta_4 \quad \text{.................. (4)}$$

Here, when it is presumed that the gradient of the incident surface is 'β', an inclination angle of incident light to an optical axis is 'ϕ_3' and an angle of reflected light to the optical axis is 'ϕ_4', and they are introduced to formula (4), we can obtain following formula (5):

$$\beta = 90° + \frac{\phi_3 + \phi_4}{2} \quad \text{.................. (5)}$$

The gradient β of the reflecting mirror 12 for making light reflected by the reflecting mirror 12 parallel to the optical axis (ϕ_4=0) is represented by following formula (6) with regard to the gradient ϕ_3 of incident light:

$$\beta = 90° + \frac{\phi_3}{2} \quad \text{.................. (6)}$$

Fig. 16 illustrates relations between the inclination angle and the gradient value of the incident surface for making light reflected by the reflecting mirror 12 parallel to the optical axis.

Here, as the inclination angle increases, that is, in the peripheral pixels of the image sensor, the gradient of the incident surface of the reflecting mirror 12 increases, which will later be explained with reference to Fig. 17.

Fig. 17 illustrates an image sensor including an array of micro reflecting mirrors 12 as optical path conversion elements in accordance with yet another embodiment of the present invention.

The method of Fig. 17 reflects light incident at different angles on each pixel to be parallel to an optical axis by using the array of micro reflecting mirrors 12 having different incident surface gradients. This method equalizes angles of light incident on photoelectric elements 1, and thus equalizes amounts of light sensed in each position of the image sensor.

Fig. 18 illustrates an image sensor including an array of micro reflecting

mirrors 12 and an array of micro lenses 5 as optical path conversion elements in accordance with yet another embodiment of the present invention.

As shown in Fig. 18, the image sensor uses both the array of micro reflecting mirrors 12 and the array of micro lenses 5. Here, the array of micro reflecting mirrors 12 convert an optical path of light to be parallel to an optical axis, and the array of micro lenses 5 condense light to photoelectric elements 1. Accordingly, the method of Fig. 18 more efficiently senses light than the method of Fig. 17, and equalizes amounts of light sensed in each position.

Fig. 19 illustrates an image sensor including an array of aspheric micro reflecting mirrors 13 in accordance with yet another embodiment of the present invention.

Referring to Fig. 19, tangent lines to the corresponding parts of incident surfaces have different gradients according to angles of light incident on the surface of the image sensor, namely distances of each pixel from the center of the image sensor, and thus aspheric micro reflecting mirrors 13 in different shapes are arranged to convert optical paths of slantingly-incident light and condense light to photoelectric elements 1. That is, the aspheric micro reflecting mirrors 13 perform the functions of the optical path conversion element as well as the condenser.

Differently from the flat surface micro reflecting mirrors 12, tangent line gradients are different at each point on the incident surface of one aspheric micro reflecting mirror 13. The tangent line gradients at each point can be calculated by formula (5).

As discussed earlier, the image sensor of the invention includes optical path conversion elements having different tangent line gradients on the corresponding parts of incident surfaces according to distances between the corresponding parts and the center of the image sensor. It is therefore required to fabricate fine structures having various tangent line gradients. It is very difficult to fabricate the fine structures according to a single process using a conventional MEMS process.

However, as shown in Figs. 20a to 20c, the fine structures having various

photodiodes is 8μm.

Referring to Figs. 21a and 21b, if the array of micro prisms 10 does not exist and the inclination angle of light is 0 or 10°, the focus is formed on the photodiodes and thus the photodiodes can sense light. However, if the array of micro prisms 10 does not exist and the inclination angle of light is 20 or 30°, the photodiodes cannot sense light.

Even if the inclination angle of light is 10°, the photodiodes having small area cannot sense a lot of light.

Figs. 22a and 22b illustrate simulation results for the image sensor including the array of micro prisms 10 and the array of micro lenses 5 in Fig. 12. Here, Fig. 22a shows the optical path of light, and Fig. 22b shows distribution of light intensity in the photoelectric element 1.

As shown in Figs. 22a and 22b, if the array of micro prisms 10 and the array of micro lenses 5 exist and an inclination angle of light is 0, 10, 20 or 30°, the focus is formed on the photodiodes and thus the photodiodes can sense light.

On the Basis of an amount of light sensed by the photodiodes at an inclination angle of 0°, when the micro prism arrangements 10 do not exist and exist, condensation efficiency is 92% and 93% respectively at an inclination angle of 10°; 0% and 90% respectively at an inclination angle of 20°; and 0% and 76% respectively at an inclination angle of 30°.

Accordingly, even when the inclination angle of light incident on the image sensor is large, the micro prisms 10 can make the photodiodes of the image sensor efficiently sense light.

Although the preferred embodiments of the present invention have been described, it is understood that the present invention should not be limited to these preferred embodiments but various changes and modifications can be made by one skilled in the art within the spirit and scope of the present invention as hereinafter claimed.

What is claimed is:

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10. An image sensor, comprising:

a substrate in which an array of photoelectric elements is formed; and

an array of optical path conversion elements for converting optical paths of incident light formed at a light incident side of the substrate so that the optical path converted light may be incident on the substrate, each optical path conversion element being formed to match with each photoelectric element,

wherein the optical path conversion elements are selected from the group consisting of aspheric micro lenses and aspheric micro reflecting mirrors, the aspheric micro lens and aspheric micro reflecting mirror having different tangent line gradient values on individual parts of an incident surface of the same optical path conversion element to condense incident light to the photoelectric element, and

the incident surface of each optical path conversion element has a tangent line gradient value to convert the optical path of light incident slantingly on a peripheral area of the image sensor at a larger inclination angle as the peripheral area is away from the center of the image sensor to be identical with the optical path of light incident vertically on a central area of the image sensor to counterbalance the inclination angle of light incident on the peripheral area of the image sensor, tangent line gradient values of corresponding parts of the incident surfaces of the optical path conversion elements at an identical distance from the respective matching photoelectric elements being different from one another according to distances between the corresponding parts and the center of the image sensor.

11. The image sensor of claim 10, which comprises both the aspheric micro lens type optical path conversion elements and the aspheric micro reflecting mirror type optical path conversion elements.

12. The image sensor of claim 10, wherein, when it is presumed that a refraction index of a layer contacting the incident surface of the aspheric micro lens is 'n_1', the inclination angle between light incident on the incident surface of the

aspheric micro lens and the optical axis is 'ϕ_1', a refraction index of the aspheric micro lens is 'n_2', and an angle of refracted light to the optical axis for light incident to one point on the incident surface of the aspheric micro lens to be refracted by the aspheric micro lens and condensed to the photoelectric element is 'ϕ_2', a tangent line gradient α at the point on the incident surface of the aspheric micro lens is represented by following formula:

$$\alpha = \tan^{-1}\left(\frac{n_1 \sin\phi_1 - n_2 \sin\phi_2}{n_1 \cos\phi_1 - n_2 \cos\phi_2}\right) .$$

13. The image sensor of claim 10, wherein, when it is presumed that the inclination angle between light incident on the incident surface of the aspheric micro reflecting mirror and the optical axis is 'ϕ_3', and an angle of reflected light to the optical axis for light incident to one point on the incident surface of the aspheric micro reflecting mirror to be reflected by the aspheric micro reflecting mirror and condensed to the photoelectric element is 'ϕ_4', a tangent line gradient β at the point on the incident surface of the aspheric micro reflecting mirror is represented by following formula:

$$\beta = 90° + \frac{\phi_3 + \phi_4}{2} .$$

14. The image sensor of one of claims 10 to 13, wherein the centers of the optical path conversion elements are offset from the centers of the matching photoelectric elements according to the distances from the center of the image sensor.

15. The image sensor of one of claims 10 to 13, wherein, when the single image sensor is divided into a plurality of regions according to the distances from its center, the optical path conversion elements in the same region have the identical tangent line gradient value on the corresponding parts of the incident surfaces, but the optical path conversion elements in the different regions have different tangent line gradient values on the corresponding parts of the incident surfaces according to

the distances from the center of the image sensor.